# DOCUMENT RESUME

ED 037 351 SE 008 091

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TITLE The Development of Models to Explain the Relation of Important Variables to Laboratory Instructional Strategies.
INSTITUTION Ohio State Univ., Columbus.
PUB DATE Mar 70
NOTE 43p.; Paper presented at Annual Meeting of the National Association for Research in Science Teaching (43rd, Minneapolis, Minne., March 5-8, 1970)

EDRS PRICE EDRS Price MF-$0.25 HC-$2.25
DESCRIPTORS *Inductive Methods, *Instruction, *Laboratory Procedures, Lecture, School Conditions, *Secondary School Science, Student Characteristics, Teacher Characteristics, Teaching Methods

ABSTRACT

Models were developed to identify important variables and their causal relationships to strategies of laboratory instruction in secondary school science. Data from student checklists, questionnaires, tests, and direct observations of laboratory activities were factor analyzed. Two teaching strategies identified by factor analysis were Inductive-Indirect Teaching and Lecture Method. Eighteen other factors were included in path analyses used to postulate and test the fit of models for the causal effect of the other factors on the two teaching strategies. Factors identified as causally related to teaching strategies were Instructional Load, Educational Level (of students), Teacher Morale, Academic Preparation of Teacher, School Size, Student Attitude, Budget, and Age of Curriculum. Educational level of students had a negative effect on both strategies, suggesting that teachers in the upper grades provide students with more written materials so that the amount of teacher talk is not necessarily a valid indicator of the degree to which a teacher uses an inductive-indirect strategy. Teacher Morale had a positive effect on inductive-indirect strategy and a negative effect on Lecture Method. (EB)

# The Development of Models To Explain The Relation Of Important Variables To Laboratory Instructional Strategies



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A paper presented at the annual convention
of the National Association for Research in Science Teaching
Minneapolis, Minnesota, March 5-8, 1970

Science educators have studied a variety of teaching methods in search of the most effective combination for promoting learning by the students. Most school learning is aimed at transfer from limited classroom experiences to practical applications under new conditions. One of the functions of science courses as given by Cronbach (1963) is to develop what are sometimes called "scientific" patterns of thought. It would be futile to try to duplicate all of the significant situations where a particular idea or skill would be used. A question that science educators must investigate is "How can science teaching methods be combined and modified to improve the transfer probability of what students learn?"

## Importance of Study

The study of this problem has centered around comparison of laboratory-centered and lecture-demonstration centered methods of science instruction and comparison of direct-expository teaching as opposed to indirect-inductive strategies. Much of the accumulated research in these areas is difficult to interpret because of many conflicting and contradictory results.

This dilemma is due to the confounding of the data by the use of a variety of methods and strategies within the laboratory treatment groups. There may be more variance within the laboratory method of instruction and between the different strategies used than there is between the methods of lecture-demonstration and laboratory instruction.

The lack of reproducibility in studies comparing the effectiveness of lecture-demonstration methods and laboratory methods of science teaching may well be due to the lack of control of variables related to the strategies used. The confounding factors involved in the variety of strategies used must be identified and their relationships resolved before they can be effectively controlled in experimental work.

> "Until a learning theory of laboratory methodology is clearly defined the results of studies of laboratory methods and other methods of teaching will continue to be contradictory, unpatterned and fragmented." (Hurd: 1964, p. 288).

This study was designed to develop models to explain the causal relationships of teacher, student, administrative, environmental, and class activity variables to the laboratory instructional strategies used in secondary school science classes.

Research comparing two or more methods of instruction too often involve variation in content, instructors, and other variables as well as method. Any differences in student performance on a criterion measure may be due to differences other than method differences. The availability of data processing equipment makes large scale analysis with many factors highly practical. In science education, possible interactions between content, method, age, and ability levels may be at least as important as the main effects themselves. Studies by Knox (1935), Johnson (1928), White (1943), Lucow (1954) and Ward (1956) were related to the differential effects of treatment on different ability levels of students. No recent studies using higher order factorial designs with random assignment of subjects to treatment groups were found. Before designs of this nature are used it is first necessary to identify the crucial variables underlying the teaching-learning processes.

There is a need for more and better instrumentation for measuring the expected outcomes of science instruction. Better observational techniques are needed to accurately and objectively assess the characteristics of classroom practices and instructional activities. General subjective ratings and opinions have some value but the reliability of such measures is low and objective instruments should be used when possible. Finally the causal influences of learning conditions need to be identified so that patterns can be recognized and interpreted. If questions are to be answered concerning the value of one strategy of laboratory instruction compared to another it is necessary to have a clear conception of what the strategies are and how they can be identified.

Laboratory strategies are influenced by a great number of variables in a variety of ways. Models for the causal relationships of these variables and the strategies of instruction used can be tested and continually improved upon by use of a combination of multivariate techniques such as factor analysis and path analysis.

These models should help to clarify the role of the major variables affecting particular strategies of laboratory instruction by describing the patterns and sequences of their influence in producing the characteristics of the instructional strategies being considered.

## Basic Assumptions

This study is directed toward two strategies of laboratory instruction. One is the expository-direct approach where students are passive learners and the other an inductive-indirect approach where students are active learners. Learning is demonstrated by students as a change in behavior as a result of experience. If these experiences are the product of activities that are organized and highly structured such that students are told what is to be learned, the students are considered to be passive learners. On the otherhand if these experiences are a result of student planning and participation with a minimum of teacher involvement, the students tend to be active learners.

An assumption underlying this study is that the combined structure of these two laboratory strategies is dualistic rather than bipolar. A dualistic or two-sided view is assumed where characteristics of one strategy may be present independent of the other strategy. Those individuals who tend to support expository methods may also support inductive methods in their laboratory instruction. In practice it was anticipated that there would be a low negative correlation between the measures of inductive-indirect strategy and expository-direct strategy.

## Definition of Terms

In this section, terms which need special clarification are defined and explained. These terms are defined specifically for the purpose of this study, and they may or may not be generally defined in the same manner.

The inductive-indirect strategy for teaching science by the laboratory method provides the student with the opportunity to formulate generalizations based on data obtained from experimental activities. This strategy places the major responsibility for learning on the student. The inductive strategy helps the student to understand the basic foundation and origin of scientific principles, concepts, and processes. In this approach the experimentation and data determine the principles and concepts of science. In other words, the student activities and experiences determine what is to be learned. The inductive-indirect approach to laboratory instruction provides for active student participation in critical thinking and inductive processes.

The expository-direct strategy is the more traditional approach to science laboratory instruction. The teacher uses the laboratory to illustrate established scientific principles and to verify facts previously learned by the students during classroom discussions and lectures. This strategy places the responsibility for what is learned with the teacher while the student is placed in a more passive role than in the inductive-indirect strategy.

The teacher employing this approach uses the principles and concepts of science to determine the means and type of experimentation. In this approach certain results are expected and experimental designs and techniques are manipulated by the teacher so as to obtain these results. A basic assumption of the expository-direct strategy is that the existing knowledge is sound, and consequently students are rarely encouraged to challenge the limitations of the present paradigms.

The expository-direct strategy is based on the simple and compelling fact that often the best way to teach students something is to tell it to them.

According to the dualistic nature of these approaches assumed by this study the presence of properties describing one strategy does not automatically exclude or include the presence of properties describing the other strategy. In practice most laboratory instructional situations are expected to include a composite of activities related in varying degrees to inductive-indirect and expository-direct approaches.

## General Plan of Procedures

The major purpose of this study is to develop causal models relating to inductive-indirect and expository-direct laboratory teaching strategies in science at the secondary level. These models should serve to identify variables critical to the nature of the laboratory strategy used and to clarify the effect of these variables upon the laboratory learning conditions. To accomplish this purpose the procedures followed were:

1. Development of instruments to measure the degree of inductive-indirect and expository-direct strategy used in a laboratory situation.

2. Identification and measurement of the relevant variables which contribute to the character of the laboratory strategy used.

3. Formulation of causal models for explaining the order and magnitude of the influence of the relevant variables on the laboratory method used.

## Preparation of Student Checklist

No standardized instrument is available which measures the degree of inductive-indirect or expository-direct strategy used in a laboratory teaching situation. An instrument was constructed for this purpose.

The instrument developed was a student checklist consisting of items describing laboratory activities and procedures characteristic of the strategy being assessed. The checklist included twenty-two items characteristic of expository-direct laboratory strategy and twenty-three characteristic of inductive-indirect strategy. Barnes (1967) and Kochendorfer (1967) developed similar student checklists to identify classroom and laboratory practices in high school biology. The major purpose of the checklist items was to determine what activities are included in the science laboratory as viewed by the students. Regardless of either the teacher's or observer's judgement, the perception of the activity by the students is what determines its effective character. A score representing the degree of expository-direct strategy was determined for each laboratory situation by totaling the number of "yes" responses to the expository scale. Likewise, the degree of inductive-indirect strategy was determined by summing the number of "yes" responses to items on the inductive scale.

A reliability coefficient for each scale of the checklist was computed by the Hoyt ANOVA method (1941). The Hoyt reliability for the expository-direct scale for all students involved in the study (N = 1446) was .505 and for the inductive-indirect scale the reliability was .669. The data from the analysis of variance used to compute the Hoyt reliability is given in Tables 1 and 2.

A teacher checklist was prepared as an adapted form of the student checklist. The original instrument was reworded so as to elicit the teachers' views concerning the value of the described activities for science laboratory instruction. This measure was taken as an indicator of the teachers' attitudes towards the use of expository-direct and inductive-indirect laboratory teaching strategies. The Hoyt reliabilities for the two scales of the teacher checklist were: expository-direct, .554, and inductive-indirect, .763.

TABLE 1

Reliability of Expository-Direct Scale of Student Checklist Computed by Hoyt ANOVA Method

| Source of Variation | Sum of Squares | df | Mean Square |
|---|---|---|---|
| Persons | 618.88 | 1445 | .428 |
| Items | 401.72 | 19 | 21.1430 |
| Error | 5815.53 | 27455 | .212 |

$$r_{xx} = 1 - \frac{MSe}{MSp}$$

$$= .505$$

TABLE 2

Reliability of Inductive-Indirect Scale of Student Checklist Computed by Hoyt ANOVA Method

| Source of Variation | Sum of Squares | df | Mean Square |
|---|---|---|---|
| Persons | 864.82 | 1445 | .598 |
| Items | 1072.49 | 21 | 51.071 |
| Error | 6014.69 | 30345 | .198 |

$$r_{xx} = 1 - \frac{MSe}{MSp}$$

$$= .669$$

## The Sample and the Population

This study was made during the spring of 1969 in the Boulder Valley Schools. 1446 students and 57 teachers in 12 school buildings participated in the study. The sample was comprised of thirty-two junior high school classes (grades 7 thru 9) and twenty-five high school classes (grades 10 thru 12). The subject matter content of the classes included biology, earth science, physical science, anatomy, advanced biology, physics, chemistry, geology, and physical science. The size of the schools selected for the study ranged from 163 to 1608. The communities serviced by the schools included a small mountain community, the large urban community of Boulder, two small rural farming and coal mining communities, and one community comprised to a large extent of families in which the wage earner commutes to his place of employment.

The Boulder Valley is heavily populated with various scientific and technological business corporations. The presence of the University of Colorado and the many corporations holding government contracts for scientific projects tends to make the community very science conscious. The average I.Q. for the students in this study was 118.35[1].

## Selection of Variables

Variables considered important to the nature of science instruction in the classroom were discussed in studies by Cunningham (1946), Colyer and Anderson (1952), Novak (1963), Rutledge (1966), Blankenship (1967),

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[1]Composite on Lorge Thorndike Test of Intelligence.

Hurd and Rowe (1964), and Kleinman (1965). This previous research was used as guidance for the selection of variables to be included in the study. The variables selected were identified by five major categories: student characteristics, teacher characteristics, environmental and administrative conditions, materials, and instructional variables such as student activities.

Sixty-five variables were measured by the use of the following instruments: student questionnaire (S.Q.)[1], teacher questionnaire (T.Q.), observation form (O.F.), student checklist (S.C.), teacher checklist (T.C.), and record form (R.F.). A listing of the variables by categories, a brief description of the measure, and the title of the instrument used to measure each variable follows.

| Student Variables | Source |
|---|---|
| 1. Sex (male or female) | S.Q. |
| 2. Age (years) | S.Q. |
| 3. Grade Level (7,8,9,10,11,12) | S.Q. |
| 4. Socio-Economic Status (Determined from parental occupation information provided by the student) using the Hatt-North Occupational Prestige Index (1947). | S.Q. |
| 5. Years of Science (number of full year science courses completed in grades 7 thru 12) | S.Q. |
| 6. Attitude (towards science course--like or dislike) | S.Q. |
| 7. Science Career Plans (yes or no) | S.Q. |

[1]These abreviations will be used in the listing of the variables to indicate the instrument used for collecting data.

| <u>Student Variables</u> | <u>Source</u> |
|---|---|
| 8. Last Grade (received on report card in science course--A,B,C,D,F) | S.Q. |
| 9. I.Q. (<u>Lorge-Thorndike Intelligence Tests</u>--composite score). | R.F. |
| 10. Achievement (composite percentile on <u>Iowa Tests of Basic Skills</u> or <u>Iowa Tests of Educational Development</u>) | R.F. |
| 11. G.P.A. (grade point average in science) | R.F. |

| <u>Teacher Variables</u> | <u>Source</u> |
|---|---|
| 1. Sex (male or female) | T.Q. |
| 2. Age (years) | T.Q. |
| 3. College Credits Science (semester hours) | T.Q. |
| 4. College Credits Course Taught (semester hours) | T.Q. |
| 5. Year Since Last College Course (education or science) | T.Q. |
| 6. College Credits History and Philosophy of Science | T.Q. |
| 7. Government Institute Participation (yes or no) | T.Q. |
| 8. Type of College (State University, State College, City College or University, Teachers College, Private School, Church Affiliated School, or other) | T.Q. |
| 9. Teacher Degree (BA or BS, Masters, Specialist, Ed.D., or Ph.D.) | T.Q. |
| 10. Teacher Experience (years) | T.Q. |
| 11. Employment Status (full time or part time) | T.Q. |
| 12. Salary (dollars per year) | T.Q. |
| 13. Teacher Attitude (toward teaching course selected for sample--like or dislike) | T.Q. |

| Teacher Variables | Source |
|---|---|
| 14. Expository-Direct Teacher Attitude (sum of "yes" responses to expository-direct scale of teacher checklist) | T.C. |
| 15. Inductive-Indirect Teacher Attitude (sum of "yes responses to inductive-indirect scale of teacher checklist) | T.C. |

| Administrative and Environmental Variables | Source |
|---|---|
| 1. Classes per day (total) | T.Q. |
| 2. Students per day (total) | T.Q. |
| 3. Laboratory time (minutes per week) | T.Q. |
| 4. Class size (number) | T.Q. |
| 5. Teacher Preparations (number of different courses taught per day) | T.Q. |
| 6. Ratio of Boys to Girls | T.Q. |
| 7. Class Status (elective or required) | T.Q. |
| 8. Budget (the amount of money spent for the class per year) | T.Q. |
| 9. Planning Periods (number per day) | T.Q. |
| 10. School Size (total enrollment) | R.F. |
| 11. Full Time Equivalent Science Teachers (the number of full time equivalents in science per school) | R.F. |
| 12. Separate Laboratory Facility (separate from the lecture discussion area or not) | R.F. |

| Material | Source |
|---|---|
| 1. Course Content | |
| A. Biology (yes or no) | S.Q. |
| B. Physical Science (yes or no) | S.Q. |
| C. Earth Science (yes or no) | S.Q. |

| Material | Source |
|---|---|
| 2. Laboratory Manual (yes or no) | R.F. |
| 3. Nature of Text (curriculum study project or other) | R.F. |

| Instructional Variables | Source |
|---|---|
| 1. Expository-Direct Strategy (as measured by the expository-direct scale of the student checklist) | S.C. |
| 2. Inductive-Indirect Strategy (as measured by the inductive-indirect scale of the student checklist) | S.C. |
| 3. Group Size (average number of students in each group during the class observed) | O.F. |
| 4. Discipline (rigid, average, or lenient as judged by the experimenter) | O.F. |
| 5. Interruptions (number of events which disturbed or distracted the students during experimental activities) | O.F. |

The following variables relate to the frequency of the student activity described as observed by the experimenter during laboratory classes. The total frequency count for each activity was divided by the total time in minutes that observations were recorded. These values were used as an index to the relative frequencies for the various student activities.

| | |
|---|---|
| 1. Preparation and Cleanup | O.F. |
| 2. Manipulation of Equipment | O.F. |
| 3. Reading Instructions (for experiment) | O.F. |
| 4. Recording Data | O.F. |
| 5. Reading Resource Material (related to experiment) | O.F. |
| 6. Observing Experiment | O.F. |

| | | |
|---|---|---|
| 7. | Writeup (of experiment) | O.F. |
| 8. | Reading Total (sum of 3 and 5) | O.F. |
| 9. | Writing Total (sum of 4 and 7) | O.F. |
| 10. | Experimenting Total (sum of 1 thru 7) | O.F. |
| 11. | Talking to Teacher | O.F. |
| 12. | Talking to Students | O.F. |
| 13. | Talking Total (sum 11 and 12) | O.F. |
| 14. | Listening to Teacher | O.F. |
| 15. | Listening to Students | O.F. |
| 16. | Listening Total (sum 14 and 15) | O.F. |
| 17. | Non-Related Activity | O.F. |

## Treatment of Data

The experimental unit in the study was assumed to be the science class. The measurements of the variables collected on the student checklist, questionnaire, and the classroom observation form were condensed by computing a mean for each variable for each class. The BMD03D (1964) computer program was used to compute a 65 by 65 intercorrelation matrix of all the variables. A factor analysis of this matrix was done using the BMD03M (1965) computer program to obtain a principal components analysis of the data based on eigenvalues and eigenvectors with unity in the diagonal. The number of factors to be rotated was determined by the Scree Method (Cattell, 1966) which led to the selection of twenty factors to be rotated, all of which had eigenvalues greater than one except for the last one which was .971. The BMD03M computes an orthogonal rotated solution by the Varimax procedure (Kaiser, 1958). In addition to the Varimax rotation an oblique transformation according to the Harris-Kaiser (1964) Independent Clusters method of oblique transformation was computed. These computations were made using the Harris-Kaiser computer program as modified by Hakstian (1969) for the inclusion of the Equamax (Saunders, 1962) orthogonal rotation procedure. The major purpose of the factor analysis was to reduce the original set of 65 variables to a smaller number of underlying factors. In addition the intercorrelations of these resulting factors were to be used as the correlations for a path analysis. It was desirable then to use a rotation that not only achieved simple structure but also maximum factor inter-correlations. The Independent Clusters analysis met these criteria.

The coefficients of the factors were examined and all variables with loadings of .30 or greater were considered in identifying and naming the factors. The intercorrelations of these factors were treated as correlations between variables for the path analysis. These composite variables were logically ordered into patterns hypothesizing causal relationships of independent variables such as student ability and teacher experience with dependent variables such as inductive-indirect teaching strategy and lecture method. The use of regression coefficients and partial regression coefficients with recursive restrictions on the nature of the causal relationships were used to compute the regression coefficients between variables not connected by postulated causal paths. These calculated values were compared to predicted values of zero to test the fit of the postulated path model. Two models were developed, one using the Inductive-Indirect Teaching factor[1] as the dependent variable and the second model using the Lecture Method factor[2] as the dependent variable.

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[1]Factor (4) resulting from factor analysis.

[2]Factor (7) resulting from factor analysis.

## Factor Analysis

The 65 variables selected for this study were intercorrelated to obtain a correlation matrix for the factor analysis. A factor analysis was computed and twenty factors rotated to obtain simple structure. The twenty factor solution accounted for 87 percent of the total variance in the 65 variables. Factor loadings with an absolute value of .30 or greater were included in the factor. The interpretation and labeling of the factors was determined primarily by loadings of absolute value .50 or larger. Factors that had large negative loadings were reflected for convenience of interpretation.

## Interpretation of Factors

Factor 1 is defined as Educational Level, the grade in school and the maturity of the students being the emphasis. The primary factor loadings were for Grade Level, Years of Science, and Age of Student. The smaller factor loadings related to conditions in the schools due to grade level of the students. Class Status (elective or required), Planning Periods, and Students Per Day, all with negative loadings, are characteristics distinguishing between junior and senior high school organization.

Factor 2 included 7 variables, all with positive factor loadings. Grade Point Average, Achievement, I.Q., and Last Grade all loaded above .80 on this factor which was labeled Student Ability.

Factor 3 was called Teacher Experience. The variables with high factor loadings were all related to the length of time the teacher had been teaching.

The two variables, Inductive-Indirect Strategy and Inductive-Indirect Teacher Attitude, load on factor 4. In addition the variables, Nature of Text and Non-Related Activity, are included by this factor. These characteristics are common to unstructured laboratory activities where student independence is encouraged. The Nature of Text variable indicates that the curriculum study materials in the various subject areas have characteristics in common with the inductive-indirect strategy used by teachers. This factor was called Inductive-Indirect Teaching and was used as the dependent variable in a path model designed to identify the causal effects of variables on the use of inductive-indirect teaching strategies.

Factor 5 is descriptive of the activities in which students were involved during the laboratory period. The major factor loadings deal with written work accompanying laboratory experimentation. The factor was called Recording Data.

Factor 6 is similar to factor 5 with high factor loadings relating to reading activities during the laboratory period. This factor was labeled Reading.

The variables with high loadings on factor 7 are listening variables. Listening to Teacher, had the highest factor loading with total listening next. These variables are descriptive of teaching strategy where the students are in a passive role as learners. Teachers with large classes are less likely to involve the students in independent experimental activity. The negative factor loading for Preparation and Cleanup indicates that class time does not include as much involvement of students in experimental activity. The variables loading on this factor all contribute to characteristics of highly structured teaching methods. This factor was labeled Lecture Method and was used as a dependent variable in a postulated model for path analysis.

Factor 8 was called School Size. The variables relating to number of science teachers and number of students had the largest factor loadings.

Socio-Economic Status loaded moderately high, apparently because the smaller communities and rural areas are served by smaller schools and the occupational standing of wage earners in these more isolated areas tends to be lower. Teacher Preparations and Expository-Direct Teacher Attitude both had substantial negative factor loadings on this factor. A correlation of .44 between Teacher Preparations and Expository-Direct Teacher Attitude, indicates that teachers with large time demands for planning are positively inclined towards expository teaching methods.

The two top factor loadings for factor 9 were related to the sex of the students in the classes. The variables, Ratio of Boys to Girls and Sex (students), were coded with opposite scaling so that one factor loading was opposite in sign to the other. Other variables with substantial positive loadings describe the type of college from which the teacher graduated and teacher attitudes toward teaching strategies. The factor is complex with the element of sex mixed with teacher preparation and attitude. Sex (teacher) had a substantial negative factor loading. This factor may be related to the identification of institutions, activities, and attitudes as "male-like" or "female-like" in nature. This factor was labeled Femininity.

Factor 10 included 3 variables. The highest loading variable was Classes Taught per Day and the factor was labeled Instructional Load.

The largest factor loading for factor 11 was for the variable, Budget. Other variables loading on this factor are related to availability of materials for use by students in laboratory activities. Listening to Students had a substantial negative loading. This variable is an indication of the time spent by students listening to other students during laboratory activity. The negative loading indicates that greater availability of materials and equipment is related to the lesser amounts of verbal interaction.

Often if materials are plentiful students work alone rather than in a group thus decreasing verbal interaction. This factor was called Budget.

Teacher Attitude has a high factor loading compared to the other variables loading on factor 12. Factor 12 was labeled Teacher Morale.

Factor 13 is primarily characterized by the variable, Writeup. This variable was a measure of student activity during the laboratory period. The writeup activities included calculations, summary, and, to a large extent, answering questions concerning experimental activities.

Factor 14 included loadings for two variables, both of which are indicative of the course work completed by the teachers in preparation for teaching science. This factor was named Academic Preparation.

Factor 15 is another factor which describes activities in which students are involved during laboratory periods. This factor was labeled Observing.

Factor 16 was labeled Verbal Interaction. The variables included are related to both student-student interaction and student-teacher interaction.

Factor 17 includes relatively large factor loadings for the variables, Discipline and Reading Instructions. These variables tend to indicate a factor related to student independence. This factor was named Discipline.

Factor 18 includes variables descriptive of the student's attitude toward the particular science class and the teacher. This factor was named Student Attitude.

Factor 19 is descriptive of the content of the science class. Both Biology and Earth Science have high factor loadings on this factor. The Earth Science course at the eighth grade level in the Boulder Valley Schools is the course most recently revised through a national curriculum study project. The negative relationship between Earth Science and the number of years since the teacher attended a college course provides information concerning the contemporary nature of the course. This factor was labeled Age of Curriculum where curriculum is considered to be inclusive of the educational content within the classroom.

Factor 20 was labeled Confusion. The variables loading the highest on this factor were Class Interruptions and Sex of Teacher. Since sex was coded with female as the higher value this factor infers some commonality between sex and class interruptions. These two variables did not correlate highly so the relationship is not clear.

## Path Analysis

Factor 4 and factor 7 from the factor analysis are most closely related to the two teaching strategies toward which this study is directed. Factor 4, Inductive-Indirect Teaching, very effectively represents the inductive-indirect strategy for teaching laboratory science at the secondary level. Factor 7, Lecture Method, was selected to investigate a model of a teaching strategy where students have a passive role in the learning process.

The intercorrelations of each of the factors with the factor selected as the dependent variable were inspected to identify factors having possible causal relationships with the dependent variable. Correlational data does not provide direct information for inferring causal relationships that exist but it does provide a means for determining conditions where causal relationships are absent. A zero correlation between two variables not only can be interpreted to mean no relationship exists but in addition it means that no causal influence is present.

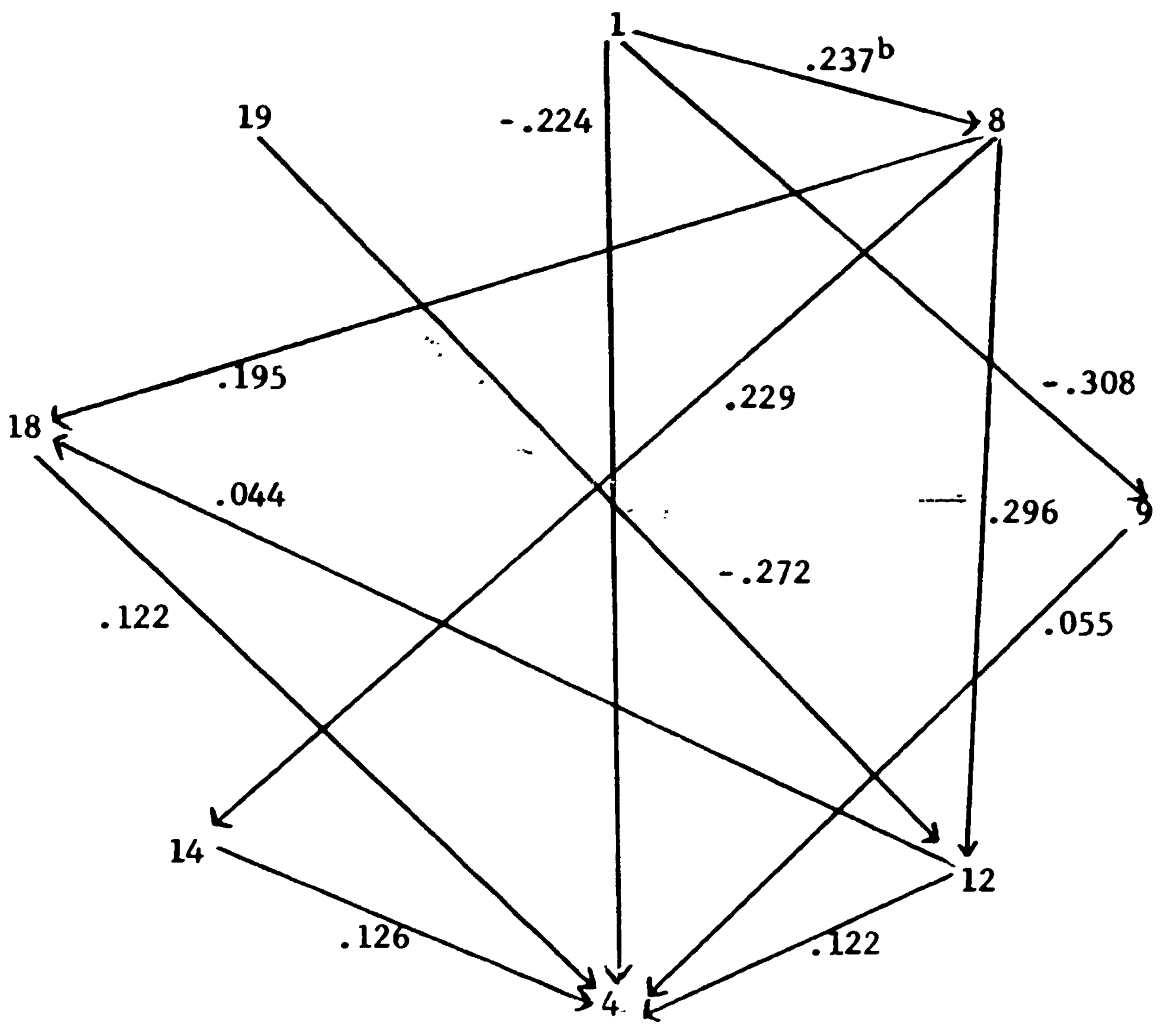
The factors with the greatest positive correlation with the Inductive-Indirect Teaching factor were School Size, Femininity, Teacher Morale, Academic Preparation, and Student Attitude. The factors with the greatest negative correlation with the Inductive-Indirect Teaching factor were Educational Level, Observing, Verbal Interaction, and Age of Curriculum. Factor 15, Observing, and factor 16, Verbal Interaction, were eliminated from the factors to be used as causal variables in the path analysis because they were considered to be dependent variables, causally affected by the inductive-indirect teaching methods.

Seven factors, Educational Level, School Size, Femininity, Teacher Morale, Academic Preparation, Student Attitude, and Age of Curriculum, were included in a recursive causal model with the factor 4, Inductive-Indirect Teaching, as the dependent variable. This model was labeled Model 1. In pairings of factors where the question of direct or indirect causal influence occurred, the intercorrelation matrix of factors was consulted. The larger correlation coefficients were used to infer possible direct causal relationship while the smaller coefficients were used to infer indirect or no relationship. The direction of these influences were decided upon by the judgment of the experimenter. A path model diagram, prepared according to the principles developed by Wright (1934, 1960), was used to represent the pattern and directional influences postulated. The order, spatial arrangement, and length of lines in the diagram are not significant properties of the representation. Arrows, connecting pairs of factors represent a direct causal relationship operating in the direction indicated by the arrow. The diagram representing the causal influences of factors on Inductive-Indirect Teaching as proposed by Model 1 is given in Figure 1.

Path regression coefficients, which are slopes of the regression lines representing the least squares estimates of the linear relations between

FIGURE 1

Path Diagram for Model 1 Representing the Causal Relationships of Factors[a] With Inductive-Indirect Teaching




[a]Variables are factors: 1, Educational Level; 8, School Size; 9, Femininity; 12, Teacher Morale; 4, Inductive-Indirect Teaching; 14, Academic Preparation (of teacher); 18, Student Attitude; 19, Age of Curriculum.

[b]Path regression coefficients.

pairs of variables, were computed from the correlations according to a series of equations of the following form:[1]

$$P_{ij \cdot k} = \frac{P_{ij} - (P_{ik})\ (P_{kj})}{1 - (P_{kj})\ (P_{jk})}$$

where $P_{ij \cdot k}$ is the path regression coefficient for the effect of factor _j_ on factor _i_ with the effects of factor _k_ held constant. These path regression coefficients are analogous to partial regression coefficients except that the path coefficients apply only to the system of variables in the postulated mode. These computations were done by means of a Fortran program prepared by Mendro (1969) for computing up to fifth order partial regression coefficients.

The regression coefficients are slopes of regression lines and are indicative of the strength of the relationship between two factors. Correlation coefficients indicate a degree of association between variables and do not provide information as to the strength of the relationship unless the correlation is zero, in which case the slope will also be zero. The path regression coefficients for Model 1 were computed for each postulated causal path as represented by the path diagram and can be found in Table 3. The path regression coefficients were computed by partialling out the effects of all other factors that have direct or indirect causal influences postulated by the model. This resulted in a path regression coefficient for each arrow in the path diagram with the magnitude and algebraic sign of the path coefficients representative of the strength and nature of the relationships.

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[1]This equation is for the computation of first order partial regression coefficients. Similar equations were used for higher order partials Blalock: p. 101, 1964).

TABLE 3

Path Regression Coefficients for Fitting Model 1

| Coefficients | Values |
|---|---|
| p 8 1 [a] | .237* |
| p 9 1 | -.308** |
| p 4 1 · 9 12 14 18 | -.224* |
| p 12 8 · 1 19 | .296** |
| p 14 8 · 1 | .229* |
| p 18 8 · 1 12 | .195* |
| p 4 9 · 1 12 14 18 | .055 |
| p 4 12 · 1 8 9 14 18 19 | .122 |
| p 4 14 · 1 8 9 12 18 | .126 |
| p 4 18 · 1 8 9 12 14 | .122 |
| p 12 19 · 8 | -.272** |
| p 18 12 · 8 | .046 |

[a]Numbers correspond to factors from factor analysis.
*Greater than one standard error.
**Greater than two standard errors.

The path regression coefficients for the postulated model may be used in modification of the model due to path coefficients of zero for postulated paths. This would indicate that the strength of the relationship is zero and that the postulated relationship between the two factors involved should be eliminated. The path regression coefficients for each direct causal effect are included in the diagram of the path mode. At this point, the model was modified by removing the direct causal effects postulated for relations with zero path coefficients.

Inspection of the path regression coefficients for the Inductive-Indirect Teaching model revealed two paths with nearly zero path regression coefficients. These relationships were between Teacher Morale and Student Attitude and the effect of Femininity on Inductive-Indirect Teaching. These low values infer no relationship in these two instances so the direct paths between each of the pairs were removed. Factor 9, Femininity was then left with no postulated effect, direct or indirect, on Inductive-Indirect Teaching. Due to these circumstances, Femininity was removed from the model and a seven variable revised model was postulated. The revised model was labeled, Model 2. The path regression coefficients for Model 2 are given in Table 4 and the path diagram for Model 2 is presented in Figure 2.

TABLE 4

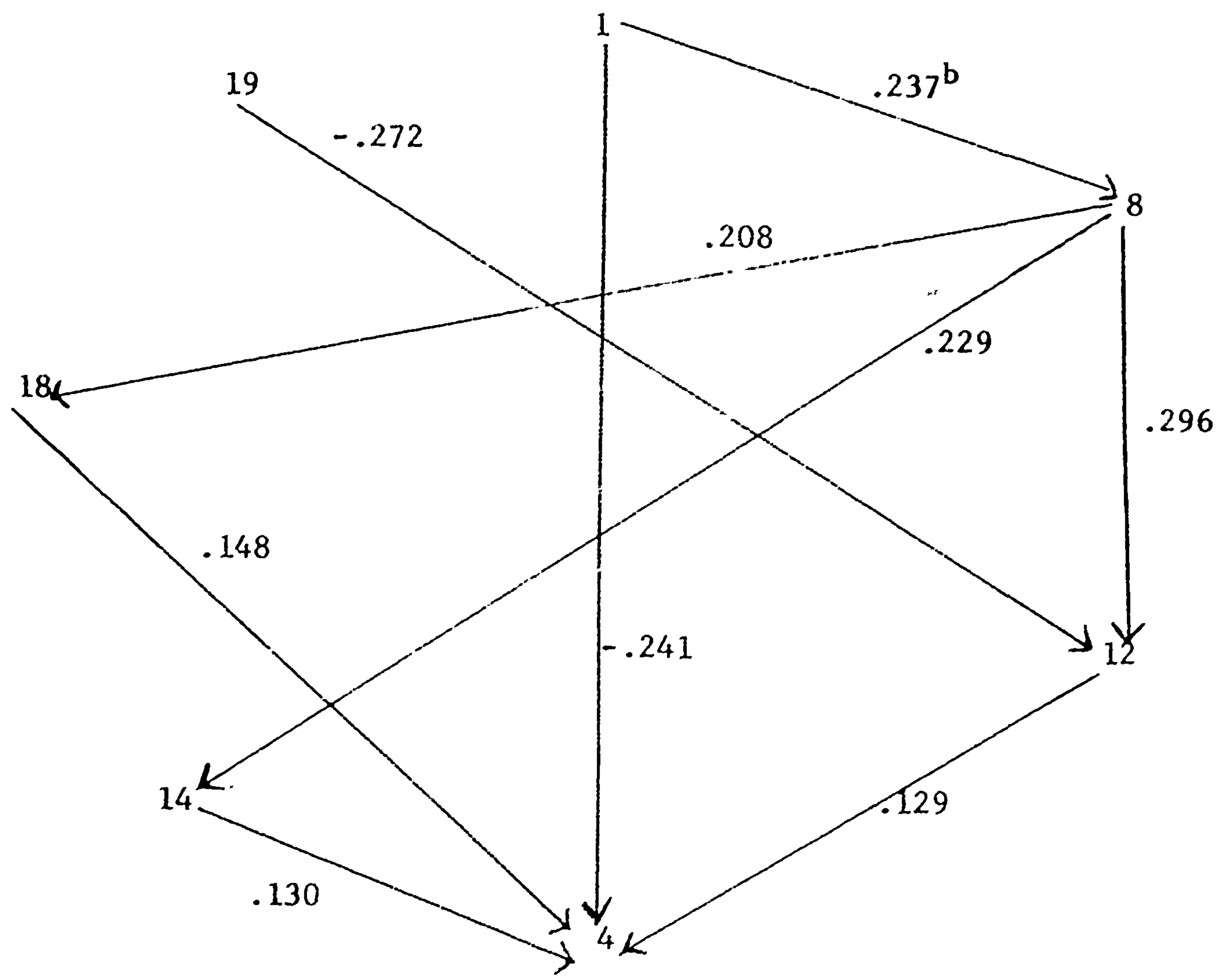
Path Regression Coefficients for Fitting Model 2

| Coefficients | Values |
|---|---|
| p 8 1[a] | .237* |
| p 4 1 · 12 14 18 | -.241* |
| p 14 8 · 1 | .229* |
| p 18 8 · 1 | .208* |
| p 4 12 · 1 8 14 18 19 | .129 |
| p 4 14 · 1 8 12 18 | .130* |
| p 4 18 · 1 8 12 14 | .148 |
| p 12 19 · 8 | -.272** |
| p 12 8 · 1 19 | .296** |

[a]Numbers refer to factors from factor analysis.
*Greater than one standard error.
**Greater than two standard errors.

FIGURE 2

**Path Diagram for Model 2** Representing the Causal Relationships of Factors[a] With Inductive-Indirect Teaching




[a]Variables are factors: 1, Educational Level; 8, School Size; 12, Teacher Morale; 4, Inductive-Indirect Teaching; 14, Academic Preparation (of teacher); 18, Student Attitude; 19, Age of Curriculum.

[b]Path regression coefficients.

To test the fit of the model the pairings of the factors for which no direct effects were postulated, were predicted to have regression coefficients of zero when the indirect effects of other factors were held constant by partialling out the influence of intermediate factors. One such prediction equation was identified for each pairing of factors where no direct relation had been postulated. If the corresponding partial regression coefficients, computed from the data, are not significantly different from zero then the test of fit of the model tends to support the causal relationships postulated. The partial regression coefficient prediction equations for testing the fit of Model 1 and Model 2 are given in Tables 5 and 6 respectively.

TABLE 5

Partial Regression Coefficient Prediction Equations for Testing the Fit of Model 1

| Prediction Equations | Actual Values |
|---|---|
| $p_{12\ 1 \cdot 8}$[a] $= 0$ | .023 |
| $p_{14\ 1 \cdot 8} = 0$ | -.019 |
| $p_{18\ 1 \cdot 8} = 0$ | .057 |
| $p_{19\ 1} = 0$ | .034 |
| $p_{9\ 8 \cdot 1} = 0$ | .029 |
| $p_{4\ 8 \cdot 1\ 12\ 14\ 18} = 0$ | .165* |
| $p_{19\ 8} = 0$ | .033 |
| $p_{12\ 9 \cdot 1} = 0$ | .022 |
| $p_{14\ 9 \cdot 1} = 0$ | .085 |
| $p_{18\ 9 \cdot 1} = 0$ | .032 |

TABLE 5-Continued

| Prediction Equations | Actual Values |
|---|---|
| $p\ \underline{19}\ \underline{9} \cdot = 0$ | .065 |
| $p\ \underline{14}\ \underline{12} \cdot \underline{8} = 0$ | .097 |
| $p\ \underline{18}\ \underline{14} \cdot \underline{8} = 0$ | .030 |
| $p\ \underline{19}\ \underline{14} = 0$ | -.026 |
| $p\ \underline{19}\ \underline{18} = 0$ | .003 |
| $p\ \underline{4}\ \underline{19} \cdot \underline{12} = 0$ | -.084 |

[a]Numbers correspond to factors from factor analysis.
* Greater than one standard error.

TABLE 6

Partial Regression Coefficient Prediction Equations for

Testing the Fit of Model 2

| Prediction Equations | Actual Values |
|---|---|
| $p\ \underline{19}\ \underline{1}^{a} = 0$ | .034 |
| $p\ \underline{12}\ \underline{1} \cdot \underline{8} = 0$ | .023 |
| $p\ \underline{14}\ \underline{1} \cdot \underline{8} = 0$ | -.019 |
| $p\ \underline{4}\ \underline{8} \cdot \underline{1}\ \underline{12}\ \underline{14}\ \underline{18} = 0$ | .165* |
| $p\ \underline{19}\ \underline{8} = 0$ | .033 |
| $p\ \underline{14}\ \underline{12} \cdot \underline{8} = 0$ | .097 |
| $p\ \underline{18}\ \underline{12} \cdot \underline{8} = 0$ | .046 |
| $p\ \underline{18}\ \underline{14} \cdot \underline{8} = 0$ | .030 |
| $p\ \underline{19}\ \underline{14} = 0$ | -.026 |

TABLE 6-Continued

| Prediction Equations | Actual Values |
|---|---|
| p $\underline{19}\ \underline{18} = 0$ | .003 |
| p $\underline{4}\ \underline{19} \cdot \underline{12} = 0$ | -.084 |

[a]Numbers refer to factors from factor analysis.
*Greater than one standard error.

## Interpretation of Model 2

Model 2 indicates that Educational Level of students has both direct and indirect influence on Inductive-Indirect Teaching. The direct effect has a negative path coefficient indicating that students in the upper grade levels, with previous science courses, influence the teacher towards the use of less inductive-indirect strategies of science teaching in the laboratory. Educational Level also has an indirect effect on Inductive-Indirect Teaching through its effect on School Size. It is difficult to interpret the educational level of the teaching-learning situation as a cause of school size without considering some additional outside influences. Higher levels of our educational system in science require more specialized equipment and centralized facilities than do the lower grades. This results in fewer attendance centers with greater school enrollments per building for high schools than for junior high schools. This causal relation seems to be confounded somewhat by outside social and economic influences.

School size affects the Academic Preparation of teachers. Large schools include a greater variety of students with broader interests, needs and abilities than smaller schools, apparently causing teachers to return to college for additional course work and training. Academic Preparation (of teachers) directly affects Inductive-Indirect Teaching. The familiarity with and knowledge of subject matter may cause teachers to use methods involving greater student participation and less formal structure. Laboratory work, planned and organized by students, often creates a wide variety of problems both in scope and in depth. The teacher with a minimum of preparation will be reluctant to use these methods.

School size has indirect effects on Inductive-Indirect Teaching via its influence on Teacher Morale and Student Attitude. This may be due to an element of prestige, associated with larger schools, which could serve to improve Teacher Morale. A positive feeling of teachers toward the courses they teach and the conditions in which they work will make them more apt to use inductive-indirect teaching methods. In a similar fashion Student Attitude will be affected by School Size. According to this model large schools tend to create more positive student attitudes toward science courses. These student attitudes stimulate teachers to involve the class in Inductive-Indirect learning situations. Factor 19, Age of Curriculum, has an indirect effect on Inductive-Indirect Teaching by way of a negative effect on Teacher Morale. According to the model the use of old materials, books, and equipment may tend to discourage teachers and prevent them from using inductive-indirect methods. On the other hand summer institutes, and new texts with fresh approaches to teaching will improve teacher morale and cause the use of inductive-indirect strategies to increase.

Path Model 3 was postulated for the causal relations of Educational Level, Instructional Load, Budget, Teacher Morale, and Academic Preparation with Lecture Method as the dependent variable. The diagram of path Model 3 is given in Figure 3. The path regression coefficients for Model 3 and Model 4 are given in Table 7. The partial regression coefficient prediction equations for testing the fit of Model 3 and Model 4 are given in Table 8.

TABLE 7

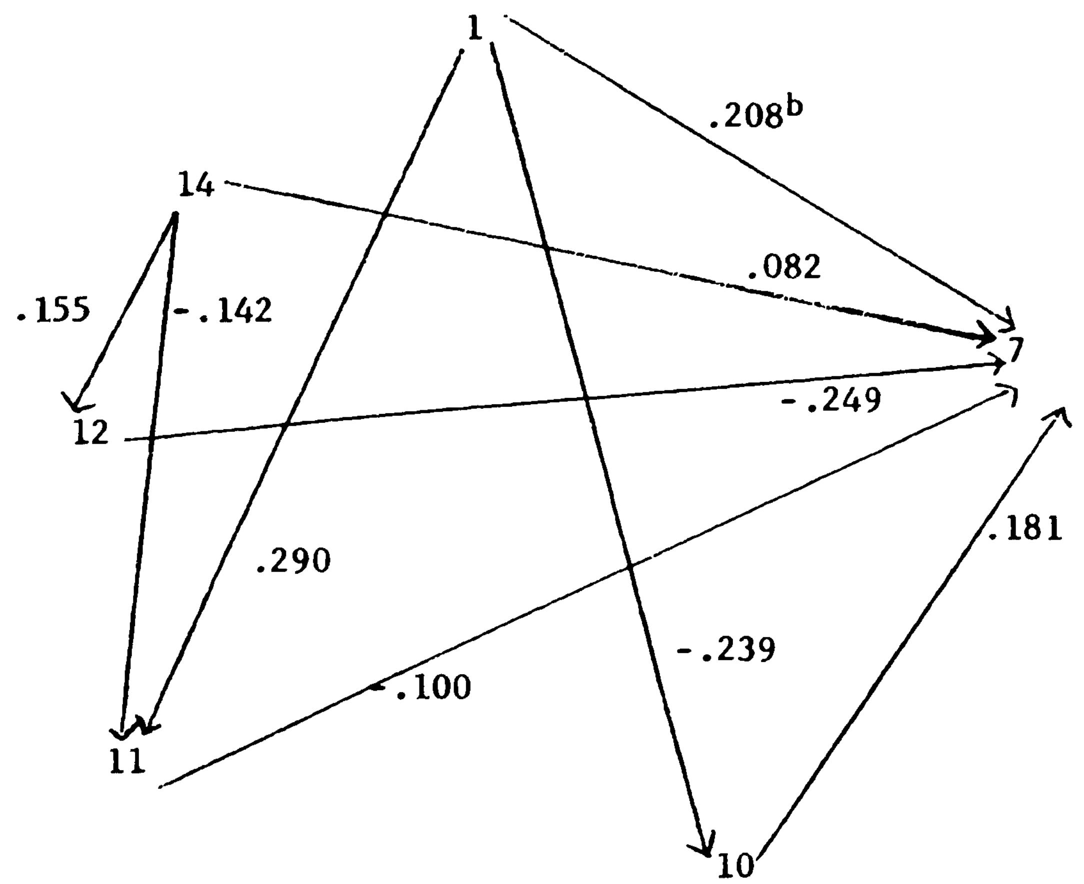
Path Regression Coefficients for Fitting Model 3 and Model 4

| Coefficients[a] | Values Model 3 | Values Model 4 |
|---|---|---|
| p 7 1 · 10 11 12 14[b] | -.208* | -.200* |
| p 10 1 · | -.239* | -.239* |
| p 11 1 · 14 | .290** | .290** |
| p 7 10 · 1 11 12 14[b] | .181* | .190* |
| p 7 11 · 1 10 12 14 | -.100 | -.100 |
| p 7 12 · 1 10 11 14 | -.249* | -.249* |
| p 7 14 · 1 10 11 12 | .082 | ---- |
| p 11 14 · 1 | -.142* | -.142* |
| p 12 14 · 10 | .155* | .155* |

[a]Numbers relate to factors from factor analysis.
[b]Variable 14 was not partialed out for Model 4.
*Greater than one standard error.
**Greater than two standard errors.

FIGURE 3

Path Diagram for Model 3 Representing the Causal Relationships of Factors[a] With Lecture Method

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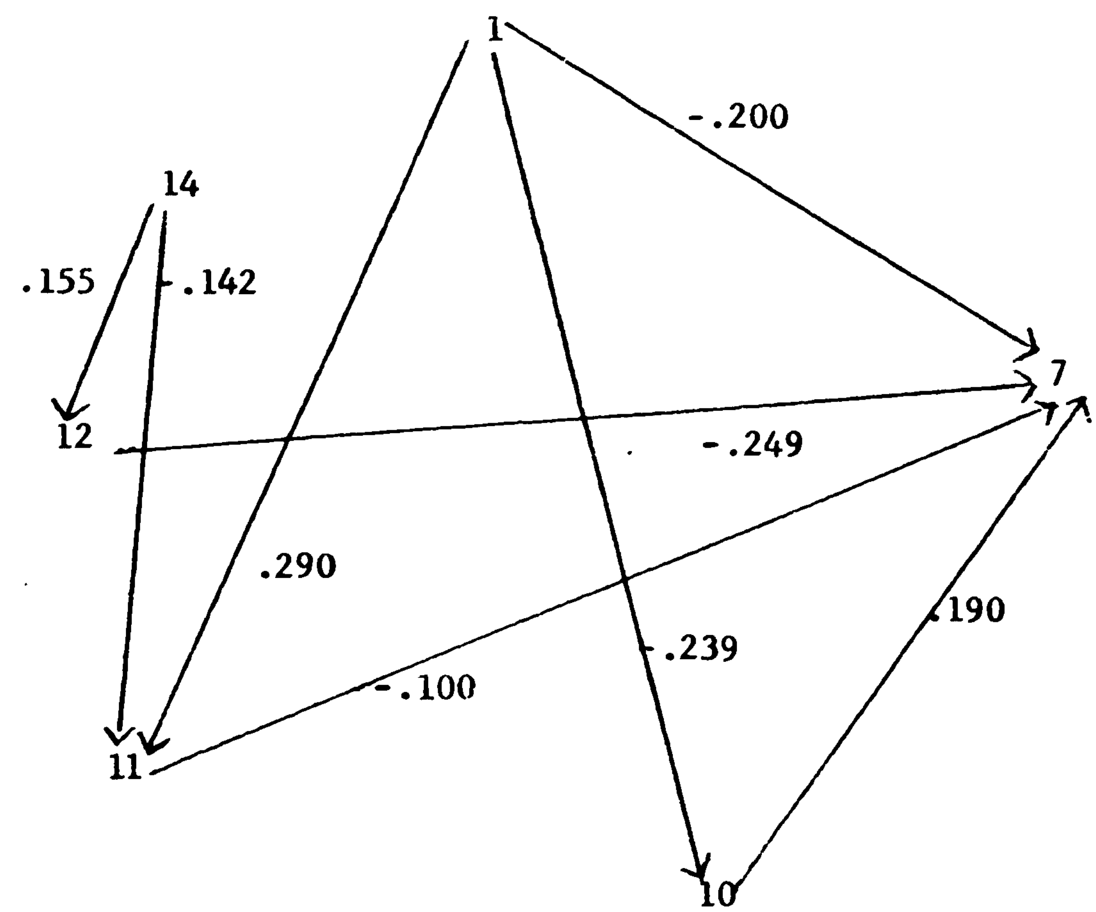
[a]Variables are factors: 1, Educational Level; 7, Lecture Method; 10, Instructional Load: 11, Budget; 12, Teacher Morale; 14, Academic Preparation (of teacher).

[b]Path regression coefficient.

FIGURE 4

Path Diagram for Model 4 Representing the Causal

Realtionships of Factors[a] With Lecture Method

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[a]Variables are factors: 1, Educational Level; 10, Instructional Load; 11, Budget; 12, Teacher Morale; 14, Academic Preparation (of teacher); 7, Lecture Method.

TABLE 8

Partial Regression Coefficient Prediction Equations and

Values for Model 3

| Prediction Equations | Actual Values Model 3 | Model 4 |
|---|---|---|
| p 12 1[a] = 0 | .091 | .091 |
| p 14 1 = 0 | .035 | .035 |
| p 11 10 · 1 = 0 | .080 | .080 |
| p 12 10 = 0 | .009 | .009 |
| p 14 10 = 0 | .089 | .089 |
| p 12 11 · 14 = 0 | .083 | .083 |
| p 7 14 = 0 | ---- | .065 |

[a]Numbers related to factors from factor analysis.

## Interpretation of Model 4

Model 4 shows Educational Level to have direct and indirect effects on Lecture Method. The direct effect is negative as it was in Model 2 for the effect of Educational Level on Inductive-Indirect Teaching. The educational maturity of students may cause the teachers to rely on written materials such as text books and laboratory manuals. According to Model 2 the content of such materials must provide direction and guidance to the students for structured laboratory activities and a minimum of Inductive-Indirect Teaching. The lower grade level student characteristics cause teachers to give verbal instruction and use more Inductive-Indirect Teaching.

The indirect effects of Educational Level on Lecture Method are through Instructional Load and Budget. Instructional Load is negatively affected by Educational Level. The maturity of older students causes the teacher to have less disciplinary responsibility than teachers of the younger classes. The science courses in the junior and senior years in high school are elective and result in smaller classes than the required courses at lower educational levels. A large Instructional Load causes teachers to rely on the Lecture Method. Teacher load must be decreased if they are expected to plan and provide more student-centered laboratory activities.

Academic Preparation has indirect effects on Lecture Method thru Budget and Teacher Morale. Model 2 did not show a direct path from Academic Preparation to Teacher Morale and resulted in a partial regression coefficient of .093. Both models show a relationship that is positive but of a questionable magnitude. Assuming the relationship postulated in Model 4, it would be interpreted to mean that a higher degree of training increases Teacher Morale. High Teacher Morale causes teachers to use more student-centered non-verbal presentation in science laboratory instruction.

The effect of Academic Preparation on Budget is the same magnitude but opposite in sign to that of Academic Preparation on Teacher Morale. This implies that teachers with more training spend less money on equipment and supplies than do the teachers just out of college. The lack of equipment and supplies may cause teachers to present information verbally. According to this model, Academic Preparation influences the use of the lecture method negatively via Teacher Morale and positively via Budget.

The causal models developed in this study, Model 2 using Inductive-Indirect Teaching as the dependent variable and Model 4 using Lecture Method as the dependent variable, both involve Educational Level of Students, Teacher Morale, and Academic Preparation of Teacher. The negative influence of Educational Level upon Inductive-Indirect Teaching in Model 2 and upon Lecture Method in Model 4 indicates that use of the lecture method does not necessarily eliminate inductive-indirect teaching strategies. Assessment of the degree of inductive-indirect teaching in laboratory situations can result in lower inductive ratings and higher expository ratings for teachers who talk when various observational instruments are used, regardless of what is said. More attention should be given to what is said by the teacher in the classroom and not just the amount of teacher talk. The influence of Academic Preparation in Model 2 and Model 4 is similar to the influence of Educational Level. Academic Preparation has a direct positive effect on Inductive-Indirect Teaching and an indirect positive effect on Lecture Method. Teachers who have more college training are inclined toward the use of inductive methods in the laboratory as well as the use of lecture methods.

Teacher Morale seems to be important in its effects on both Inductive-Indirect Teaching and Lecture Method. The opposite signs for the influence of these variables in the two models shows the tendency for the teachers with positive attitudes to use inductive-indirect laboratory methods and less verbal presentation. This factor is an aspect of teacher differences which may be a major confounding variable in studies comparing one method of science teaching with another.

## Summary and Conclusions

Generalizations of the results of this study are limited by the characteristics of the population sampled and the accuracy of the models postulated. All inferences and conclusions expressed in the following section are based upon the acceptance of the models developed.

The final models for Inductive-Indirect Teaching and for Lecture Method both included large negative influences of Educational Level on the method of laboratory instruction. Students at a more mature level of education cause teachers to use less Indirect-Inductive Teaching and less Lecture Method in science laboratory instruction at the secondary level. It can be concluded from these findings that teachers of students at high educational level within the secondary grades, provide structure for laboratory activities through the use of methods other than lecture. The educational maturity of high school students may cause teachers to use written materials which completely structure the student activities.

According to this study the particular strategy or combination of strategies used by teachers in secondary science laboratory is influenced by Teacher Morale. In the model for Inductive-Indirect Teaching a small positive effect resulted while for the Lecture Method a large negative influence was discovered. Lack of control for this factor in experiments comparing science teaching in the past, may have been a source of confounding.

Science education research is being conducted in efforts to identify the best way to provide students with the knowledges and skills that science educators feel students should have. The identification of the best methods will involve randomization to control for factors such as Teacher Morale, Instructional Load, Academic Preparation, Student Attitude.

It is generally not feasible to include these factors as main effects in a factorial experimental design. Other variables which could be controlled by randomization or used as independent variables for factorial studies are Educational Level, School Size, and Age of Curriculum. This study suggests an interaction between Educational Level and the use of certain laboratory methods of teaching. There may also be an interaction between Educational Level and method of teaching laboratory science when criterion measures of achievement, attitudes toward science, understanding of the processes of science, critical thinking abilities, and technical skills are considered as dependent variables. Once experimental studies have been made to accurately determine which laboratory teaching strategies are more effective and at what educational levels, the question of changing teachers' methods becomes appropriate. Effective approaches to bringing about such changes may be identified using the results of this study. Causal paths with high path coefficients will have the greatest influence on the dependent variable although the causal variables in these relations may not be easily manipulated. For the Inductive-Indirect Teaching model in this study, the manipulation of Educational Level would not serve the purposes intended. There would be little advantage to the students and the system in moving a teacher from one educational level of teaching to another in order to change the methods used by the teacher. It would be more appropriate to focus on such factors as Teacher Morale, Academic Preparation, and Age of Curriculum even though the direct causal effects on use of teaching methods may be small. The science educator should give particular attention to these three areas.

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